Student Engagement and Educational Benefits of Web GIS-Based Projects

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ABSTRACT

The evolution of geographic information systems (GIS) based on the internet (Web GIS) created new opportunities for the use of GIS technology in education. In the present study a learning environment was developed which incorporates the project-based learning (PBL) methodology based on Web GIS technology. In this context, 3 research projects (GIS based projects) were designed and implemented. Project 1 and 2 combined fieldwork and GIS, and the topic was related to local community issues. Project 3 was an internal project since it was conducted only in the computer lab with data collected from the internet. In order to investigate the effectiveness of this learning environment in students' engagement, a quasi-experimental study was conducted on 58 senior high school students. A pre-test was conducted in advance and a post-test upon concluding all three projects. The results reveal the pedagogical value of the aforementioned learning environment, since it provides multiple pedagogical benefits, having a positive effect on students' engagement.

KEYWORDS

Spatial Thinking, GIS-Based Project, STEM Education, Students Engagement, Web GIS

1. INTRODUCTION

Geographic Information Systems (GIS) are integrated computing systems for collecting, editing, and analyzing data. Web GIS is based on the cloud technology and are composed by a collection of mobile device native apps that help researchers accumulate, map and analyze authentic field data. According to Bednarz (2000), the Project-Based Learning (PBL) methodology is suggested as the best method for teaching and learning scientific skills when supported by proper educational technology. As Web GIS consists of powerful tools and methods for capturing, mapping and analyzing spatial and non-spatial data, they can technologically support the PBL methodology (Sofias & Pierrakeas, 2021). The combination of GIS technology with the PBL teaching method can increase learning outcomes in regard to analytical and critical thinking (Liu et al., 2010). Besides, "spatial thinking and STEM learning are correlated longitudinally as well as cross-sectionally" (Newcombe, 2017). Projects that are based on GIS technology (GIS-Based Projects) can be described as projects carried

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out to answer questions such as: "What is there?" and "Why is there?" or to understand a problem using GIS technology in the production, collection, analyzation, presentation, and visualization of data (Demirci et al., 2013; Fitzpatrick, 2001).

The advent of Web GIS, cloud computing, the ability to record data in the field using mobile devices and native applications, online open geospatial data, and the professional development of teachers and schools with modern laboratories, have created new opportunities and challenges for the utilization of the GIS technology in school education (Edelson, 2014; Kerski et al., 2013).

In light of the aforementioned technological evolution, a learning environment for school education that incorporates the PBL learning model as technologically supported by Web GIS was developed, with the view to answering the following research questions and providing some documented data as to the following research gap: Can the design and implementation of a research project within a learning environment that incorporates the PBL learning methodology, based on Web GIS technology, enhance students' engagement and is this potentially affected by gender? After all, the specific field of research concerning the connection that students acquire with their society, as well as the pedagogical benefits they gain as a result of conducting GIS-Based Projects, was recognized by Baker et al. (2012) as one of the six research gaps related to GIS in education.

Therefore, the novelty of this research lies both in developing the above-stated learning environment and in the degree of impact such an environment can have on students' engagement.

1.1 Factors That Contribute to Student Engagement

Students' engagement is "a multi facial and dynamic phenomenon that varies according to the individual, the rhythm, the activity and the time" (Lawson & Lawson, 2013) and contains "ways with which students actively participate in the shaping of their learning experience" (Trowler, 2010).

Student engagement is a dynamic situation that is shaped by environmental and individual factors. As far as the former are concerned, what is meant is the educational environment and the interpersonal relationships that are developed in it. Students best develop inner motivation of learning and engage in the learning process when they realize that their educators assign tasks that intrigue them, relate these tasks to elements from the real world, enhance their self-efficacy, praise their effort, and use formative assessment (Willms, 2003).

Individual factors are inner bonds related to school, self-regulated learning, and motivation. Emotional engagement is associated with the concept of school commitment and intrinsic motivation, behavioral engagement is associated with the manifestation of behaviors to achieve high motivation, while cognitive engagement is associated with the concept of self-regulated learning (Willms, 2003).

1.2 How Student Engagement Can Be Measured

Student engagement can be measured both qualitatively and quantitatively. A wide range of indicators can be used for both approaches, which reflect the different meanings of student engagement (Zepke, 2014). Although it is commonly accepted that student engagement is important for the learning process, there is not a common, widely accepted definition of its meaning and measurement. Most researchers agree that it contains multiple dimensions whose number and nature remain unclear. Some researchers evaluate three major dimensions: behavioral, emotional, and cognitive engagement (Fredricks et al., 2004), while others add the academic dimension as well as the support of educators and their interpersonal relations (Appleton et al., 2006).

Remarkable examples of large-scale quantitative study are the international research programs by the International School Psychology Association (ISPA) Research Committee, which evaluated the three basic dimensions of student engagement and the research program of NSSE (National Survey of Student Engagement) with five scales of engagement: reaction of students to academic challenge, active learning, interaction with educators, supportive learning environments, and enrichment of educational experiences (Zepke, 2014).

On a smaller scale, there are many research methods that can be used in the classroom to evaluate student engagement. One method, which is often used by researchers and matches the framework of the present study, makes use of the self-reported measurement tools that can be used in the form of questionnaires, particularly that of Linn et al. (2005). This method is widespread and allows the multi-facial character of student engagement to depict itself through separate indicators that evaluate cognitive, behavioral, and emotional aspects of student engagement (Chapman, 2003).

1.3 GIS and Student Engagement

Generally, a limited number of researchers have examined the impact of GIS on student engagement, learning, and efficiency on school education (Egiebor & Foster, 2019). As far as the promotion of positive attitude and student engagement is concerned, Kerski (2003) maintains that: "GIS increased student motivation for geography, altered communication patterns with fellow students and with teachers, stimulated students who learn visually, and reached students who are not traditional learners." (Kerski, 2003). Moreover, students who showed an augmented interest in GIS-Based Projects found these projects could reinforce freedom in the classroom and in the acquisition of basic knowledge of geography (Milson & Earle, 2008).

In another study, the data analysis of students' interviews revealed that both the theoretical approach (with abilities that are obtained by solving an authentic planning problem) and the practical method of learning were significant in student engagement with the use of GIS (Madsen et al., 2014).

As a teaching tool, GIS makes it easier to consolidate the content of teaching through practical use of knowledge. They make learning entertaining, allow easy access to data and information, ameliorate knowledge of maps, and finally, encourage critical thinking (Aladag, 2014).

Goldsmith (2016) examined the impact of a GIS-Based Project of social interest on student engagement by conducting a case study on students 11–13 years old. In her conclusion, she reports that GIS can increase the engagement of students in learning to a certain degree and that the obstacles for their fuller engagement can be avoided through more careful planning that is worth the time and effort (Goldsmith, 2016).

To conclude, a new educational context is formed with the appearance of cloud technology tools like Web GIS, and consequently, new technologically supported learning environments can be developed in order to strengthen education outcomes.

2. METHODOLOGY

The present study aims at developing a school learning environment based on Web GIS technology using the Project-Based Learning (PBL) methodology. Accordingly, three projects related to real-world issues were implemented. Projects 1 and 2 addressed local community issues and both included authentic field data collection, using mobile devices with GPS, while Project 3 was related to a global issue and was carried out only in the classroom, based solely on web data. With the aim of investigating the impact of such a learning environment on students' engagement, a mixed methodology approach was used. On a quantitative basis, quasi-experimental research was conducted with a non-random sample of students. The data collection process involved having participants take a self-assessment questionnaire before and after. On a qualitative basis, participant observation was used as a method of qualitative research.

2.1 Sample Analysis

To investigate the impact of such a learning environment on student engagement, quasi-experimental research with 58 senior high school students (Lyceum of Vrachnaiika) took place in the school year 2019–2020. Two work groups were formed, one for the implementation of Projects 1 and 2 (Group1) and the second only for Project 3 (Group2). Group1 consists of 38 students, aged 15–16 years old from two individual classes (A1 and B2) and Group2 consists of 20 students, aged 15 years old from class A3. The two groups were both tested separately (Group1 vs. Group2) and as a whole group (Total) (Table 1).

2.2 Geographic Survey Area

The General Lyceum of Vrachnaiika is an upper secondary public school in Vrachnaiika, part of the wider urban complex of Patras and an administrative unit of the Municipality of Patras in Achaea, Western Greece. Most of its students belong to working class and farmer families residing in surrounding rural areas.

Based on the latest available census data (National Census of 2011), the population of Vrachnaiika amounts to around 4,600 inhabitants (see https://en.wikipedia.org/wiki/Vrachnaiika). For the purposes of the present study, its geographical area will be cited as the "survey area" in the context of Projects 1 and 2, while for Project 3, the "survey area" will comprise the whole of Greece.

2.3 Data Collection Tool

The assessment of student engagement used the Student Engagement Chart (SEC) scale. The measurement tool (SEC) was developed by Linn et al. (2005) to assist teachers in collecting quality data related to students' engagement when they use GIS technology in the learning process. The SEC tool includes 24 indicators in tabular form and is based on the study by Chapman (2003). Teachers complete the above tool during the GIS-based course by grading the classroom climate on engagement indicators from the tool, as compared to a regular course (regular column), from very rare to very frequent. Verbal commentary has been added to each percentage quota for further interpretation (Linn et al., 2005). Thus, if during a GIS lesson it is observed that an indicator of learning engagement from the tool has a frequency of about 50% compared to the normal lesson, the teacher marks the corresponding cell.

In the present study, the above tool was used to gather both quantitative and qualitative data. Specifically, the SEC tool was adopted with minor modifications in the present study to be used by the researcher as a key to observe learning engagement in various phases of the educational intervention. To statistically process the data collected with the SEC tool, the verbal annotation of each column was matched.

Thus, the findings can be analyzed by calculating the average value of all observations received in the various phases of the educational intervention. The difference between the mean value (DM) and the control value 3, which represents the usual (normal) class climate, is then calculated.

Regarding the use of the SEC for the collection of quantitative data, this was done by turning it into a self-reported questionnaire of 24 statements, which the students filled in before and after the educational intervention. The answers were measured based on the degree of agreement of the students with each sentence in the five-point Likert scale, where 1 represented "strongly disagree" and 5 "strongly agree" and therefore, the highest possible score was 120 points. The score of negative sentences was reversed with 1 representing "strongly agree" and 5 representing "strongly disagree" (Goldsmith, 2016).

Table 1. Analysis of sample size

	N	Male	Female	Group Description	Projects
Group1	38	23	15	Students from A1 & B2 class	1, 2
Group2	20	12	8	Students from A3 class	3
Total	58	35	23	All students	1,2,3

2.4 Statistical Criteria

To assess the efficacy of the learning environment (independent variable) on student engagement (dependent variable), t-tests were used, signaling statistical significance if the p-value<0.05. Pre- and post-test scores were compared by taking a Paired Samples t-test to understand whether students significantly improved their spatial thinking skills after they finished the Web GIS-Based Project. To compare the two score means between the genders as well as the two groups, an Independent Samples t-test was conducted before and after the educational intervention. Lastly, to measure the Effect Size of the educational intervention on students' spatial thinking skills, Cohen's d was calculated. The calculation involves taking the score mean difference between two groups and dividing the result by the pooled standard deviation. Some typical Cohen's d values are referenced in Table 2.

2.5 Description of the Three Student Research Projects

In order to execute these three research projects, the Chen (1998) and ESRI (2020) methods for conducting GIS-Based Projects in class were adopted in combination, as illustrated in Figure 1. As Web GIS software, the ArcGIS Online mapping platform was used.

2.5.1 Phase 1: Project Planning and Design

Students belonging to Group1 were tasked with researching the main problems in their local society, environment, and economy, and coming up with solutions. During dedicated meetings, the proposed project topics were assessed based on their relevance as well as their feasibility in terms of the students' familiarity with the issue at hand, availability of data and equipment, and constraints at the school level, etc. (Demirci et al., 2013). Three projects were finally selected (Table 3). The first two projects were conducted both indoors and outdoors (at the school computer lab and at the survey field), while the third project, due to its connection to the current global health crisis, was conducted indoors only, at the school computer lab, and is an example of an internal GIS-Based Project.

At this phase, and before planning the activities, the teacher, following the directives of Demirci et al. (2013), Kotsopoulos (2010), and Favier (2013, p. 80), which state that students should first

Table 2. Effect Size scale Cohen's d (Huck, 2008)

	Small Effect	Medium Effect	Large Effect
Cohen's d	0.20	0.50	0.80

Figure 1. Phases of conducting a GIS-based project

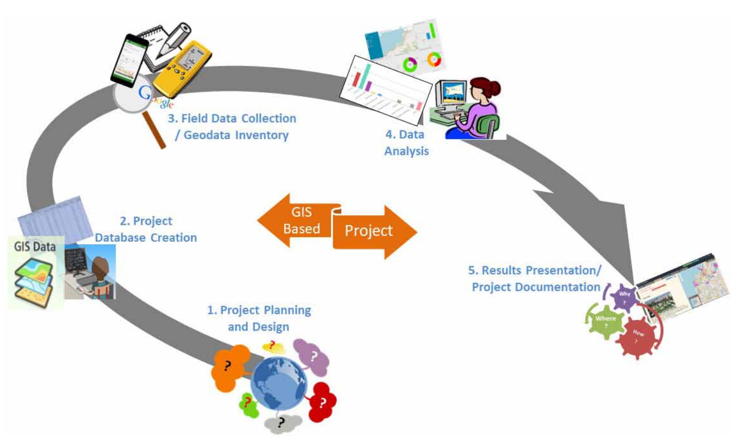


Table 3. Description of GIS-based projects

Topic of GIS-Based Projects	Group	Duration	Place
Sidewalk inventory of the survey area	Group1	One School Year	Computer Lab & Research Field
Recycling and waste bin inventory of the survey area			
Creation of an interactive application that maps the geographical distribution of the recorded confirmed cases and deaths of Covid-19 in Greece.	Group2	One Semester	Computer Lab

learn *how* to use GIS tools and *then* use them to learn, conducted a series of workshops on the basic functions of the ArcGIS Online platform. It should be noted that throughout the implementation of the projects, there was further targeted training of students on the ArcGIS Online platform applications (ArcGIS Survey123, ArcGIS Collector, ArcGIS Insights, ArcGIS Story Maps) related to the planned activities of the projects.

2.5.2 Phase 2: Database Creation

At this phase, the development of a digital geospatial database (geo-database) took place, based on the existing data and what was to be collected. Therefore, in addition to digital capturing in the field, data were often sought from other sources such as the cadaster, town planning services, the army register, universities, etc.

Regarding Project 1, the geo-database with the corresponding feature layer was to include the spatial data for the streets of the research area. As for the geometric information, it was obtained from Open Street Map (OSM)—a global community that offers free map data—in the Shapefile spatial data format. The Shapefile derived from OSM represents the streets as lines with the corresponding geometric information and does not contain any information about the sidewalks.

Regarding Project 2, the goal was to create a feature layer that would consist of points representing waste bins along with their descriptive features. This feature layer was created with the ArcGIS Survey123 application, which offers the ability to design surveys for rapid data collection through smart forms. The fields of such a form are essentially the fields of a feature layer, which is automatically created on the ArcGIS Online platform (Hosted Feature Layer). The same app was used to create a feature layer consisting of points representing the obstacles on the sidewalks.

As for Project 3, a feature layer was created that included the boundaries of the 54 prefectures of Greece and the fields for the project-related descriptive features. Regarding the geometric information about the boundaries of each prefecture, it was obtained from the Organization of Land Registry and Mapping of Greece in Shapefile spatial data format. The fields used by this Shapefile were the name, the population and capital city of the prefecture, and the geometric characteristics (boundaries). The attributes (fields) added to this thematic level were the confirmed Covid-19 cases and the confirmed deaths by Covid-19.

2.5.3 Phase 3: Field Data Collection — Geodata Inventory

The introduction of descriptive data into the Geographic Information System (GIS) created for Project 1 involved two phases, the first in the computer lab and the second in the field of survey. In the first phase, the students used Google's Street View application to determine the existence of sidewalk(s) on a street by updating the geodatabase accordingly. In the second phase, the teams moved to the respective building blocks and only to the streets with sidewalks, recording the descriptive characteristics of the sidewalks (width, condition, paving, bar for the disabled). For the capturing, they used their smartphones with active GPS, the ArcGIS Collector application, and a measuring tool (meter). In both phases the students worked in teams, each team undertaking the mapping of specific building blocks and each member of the team covering specific streets.

For the capturing of the location and the descriptive features of the waste bins in the research area, the same procedure as for Project 1 was followed.

Finally, regarding Project 3, students undertook daily data entry work in the ArcGIS Online platform. This was a simple process of a few minutes, after visiting the iMEdD GitHub and the National Health Organization website.

2.5.4 Phase 4: Data Analysis

At this phase, students used the ArcGIS Online analysis tools and apps to analyze the spatial and non-spatial data of the projects, i.e., asked questions to the GIS so as to get the appropriate answers in the form of maps, diagrams, tables, etc.

As already mentioned, the first and second projects shared common activities and objectives and therefore, at the analysis phase they were treated as a single project. After all, the students who participated in the implementation of these projects are considered by the present study as a single group (Group1). The first result of the two projects was a web-map with the three feature layers that were created in phase 2 (sidewalks, obstacles on sidewalks, and waste bins) and the corresponding base map (Figure 2).

Students used the aforementioned web-map to ask questions such as: How many bins were mapped? How many of them were recycling, waste, or glass bins (Figure 3)? How many bins were in poor condition? What was the most common damage? In which locations are the poorly maintained bins? Which streets have one or two sidewalks? How many sidewalks are more than two meters wide? How many of them have a bar for the disabled? Which sidewalks have obstacles? What were the most common obstacles?

In the third project, data analysis included the creation of a web-map showing the confirmed cases and deaths from Covid-19 by prefecture. In addition, the students used the ArcGIS Insights application to create an Insights Workbook that included spatial and non-spatial analysis in high-quality visualizations with maps, tables, and graphs (Figure 4). Thus, the students studying these findings came up with answers to a variety of questions such as: Which prefecture has the most cases or deaths? How many cases does the region of Western Greece have? Which prefecture has no cases or deaths at all? On which day were most of the cases recorded, etc.?

2.5.5 Phase 5: Results Presentation — Documentation of the Project

At this stage students were asked to record the results of spatial and non-spatial analysis documenting their work in a final report. Both groups chose to present their results with a story map, an appropriate

Figure 2. 3D web-map—sidewalks, obstacles on sidewalks, and waste bins

Figure 3. Distribution of 286 waste bins by type

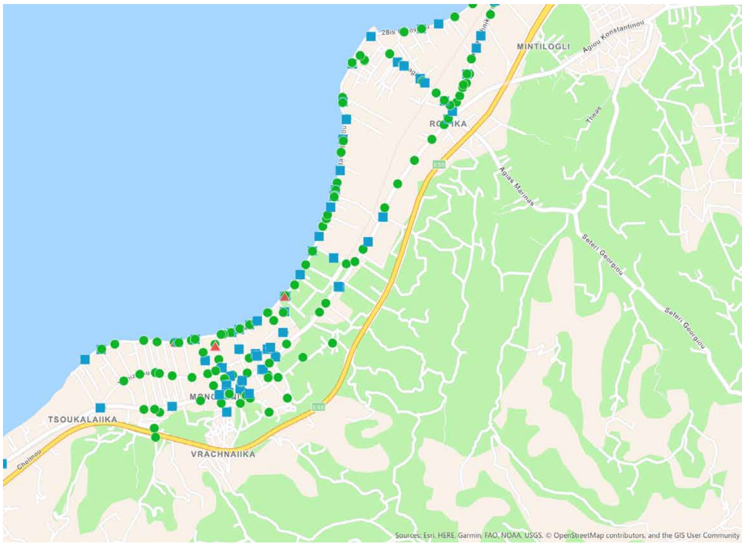
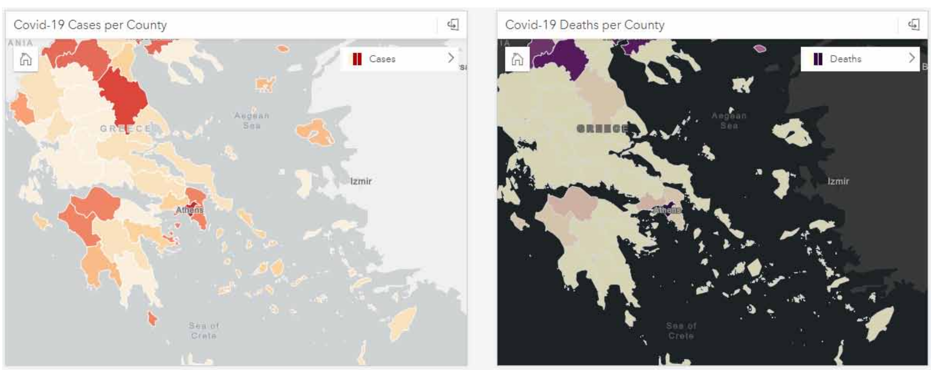


Figure 4. Data analysis representation in ArcGIS Insights



and impressive choice as these are simple web applications that combine interactive maps, multimedia content, diagrams, and reports.

In brief, Table 4 presents in a coded manner all the activities carried out during the implementation of the three research projects.

3. FINDINGS

The question of the present study is whether the design and implementation of a research project within a learning environment that incorporates the PBL teaching model based on Web GIS technology, can enhance student engagement. To quantitatively answer the question, all participating students filled in the Student Engagement Chart questionnaire (Goldsmith, 2016) both before and after the educational intervention. To qualitatively answer the question, data was collected using the participant observation method. The researcher used the Student Engagement Chart as an observational tool, as described by Linn et al. (2005) and analyzed in Section 2.3.

Table 4. Activities carried out during the implementation of the research projects

Project activities	Group1		Group2
	Project 1	Project 2	Project 3
Fieldwork	Yes	Yes	No
Field data collection	Yes	Yes	No
GPS use	Yes	Yes	No
Smartphone use for data collection	Yes	Yes	No
Web-based data collection	Yes	Yes	Yes
Using Google Street View	Yes	Yes	No
Getting acquainted with basic features of the platform	Yes	Yes	Yes
Web-map creation	Yes	Yes	Yes
Adding existing feature layers to the web-map	Yes	Yes	Yes
Styles and pop-ups configuration in web-map	Yes	Yes	Yes
Database creation	Yes	Yes	No
Using “split” tool	Yes	No	No
Using Survey123 app for field data collection	Yes	Yes	No
Using Collector from ArcGIS app	Yes	No	No
Data analysis using Insights for ArcGIS	Yes	Yes	Yes
Story map creation	Yes	Yes	Yes

3.1 Quantitative Analysis

A student t-test split by group and gender was implemented to conduct the analysis.

3.1.1 Results by Student Group

According to the Paired Samples t-test results, student engagement increased significantly both for GIS-All as well as Group1 and Group2, given the statistically significant difference in the average scores before and after the educational intervention ($p<0.05$) (Table 5). Specifically, the Effect Size of the educational intervention to students’ engagement was medium for GIS-All (Cohen’s $d=0.73$) and large for GIS-1 ($d=0.82$) with p-value $p=0.00<0.05$ for both. On the contrary, GIS-2 saw a medium Effect Size ($d=0.59$) and p-value $p=0.016<0.05$.

To investigate whether there was a statistically significant difference between the total average score of Group1 and the total average score of Group2, for both before and after the educational intervention, the Independent Samples t-test was applied (Table 6). According to the findings, there

Table 5. Paired samples t-test for all groups

Group	N	Pre-Test		Post-Test		DM	P value	Cohen’s d
		Mean	SD	Mean	SD			
Group1	38	82.05	9.59	92.00	14.17	9.95	0.000	0.82
Group2	20	79.75	11.57	88.85	13.18	9.10	0.016	0.59
Total	58	81.26	10.27	90.91	13.80	9.65	0.000	0.73

Table 6. Independent samples t-test by group

	Group1 (N=38)		Group2 (N=20)		DM	P value
	Mean	SD	Mean	SD		
Pre-Test	82.05	9.59	79.75	11.57	2.30	0.422
Post-Test	92.00	14.17	88.85	13.18	3.15	0.414

was no statistically significant difference between the total average score of the groups (p> 0.05), for both before and after the educational intervention, which means that students' engagement in both groups was at about the same level. The result was expected, as according to the findings of the Paired Samples test (Table 6), for both groups the score improved statistically significantly after the educational intervention.

3.1.2 Results by Student Gender

Does gender play a role in enhancing students' learning engagement? In this section, initially, the focus was on whether there was a statistically significant difference between the total average score of the two genders in group Total, applying the statistical Independent Samples t-test both before and after the educational intervention. The results of the tests (Table 7) showed that the total average score of each gender did not differ by any statistically significant amount before and after the educational intervention, since the p-value in all cases was above 5% (p>0.05). Analyzing the results, it can be concluded that the learning involvement of both genders before and after the educational intervention was almost at the same level. To investigate whether the two genders differed in the degree of enhancement of their learning engagement after the educational intervention, the Paired Samples test needs to be used.

Thus, according to the Paired Samples t-test (Table 8), the difference between the total average score before and after the educational intervention for both genders was statistically significant (p= 0.000<0.05 and p=0.001<0.05). The Effect Size of the educational intervention on student engagement was large for both genders (Cohen's d=0.81 and d=0.70). Therefore, both genders' improvement was statistically significant after the educational intervention and, taking into account all the findings of Table 8, females showed higher improvement.

Table 7. Independent samples t-test by gender

		N	Female		Male		DM	P value
			Mean	SD	Mean	SD		
Total	Pre-Test	58	82.87	10.57	80.20	10.08	2.67	0.337
	Post-Test	58	94.48	15.84	88.57	11.95	5.91	0.112

Table 8. Paired samples t-test by gender

		N	Pre-Test		Post-Test		DM	P value	Cohen's *d*
			Mean	SD	Mean	SD			
Total	Female	23	82.87	10.57	94.48	16.84	11.61	0.001	0.81
	Male	35	80.20	10.09	88.57	11.95	8.37	0.000	0.70

3.2 Qualitative Analysis

The qualitative answer to the research question initially involves the quantitative investigation of the SEC tool indicators, which played an important role in varying the degree of enhancement of learning engagement between groups. To do this, the difference between the total average score before and after the educational intervention was calculated separately both per group and per indicator. Then, for each indicator, a comparison of the difference-in-means (DM) was performed between the groups (Fig. 4a). The same procedure was followed for the qualitative investigation of the indicators of the observation key SEC (Fig. 4b).

Studying Figure 5, it is evident that most indicators of student engagement, both Total and Group1 and Group2, improved significantly (DM>0). In addition, in most indicators there was a consistency between quantitative research and observations. This conclusion is reinforced by carefully studying the graphs 8a and 8b which, in general, follow a similar pattern, which means that the quantitative result of the research is sufficiently supported by the qualitative one.

Figure 5. Comparison of quantitative data, graph (a) and qualitative data, graph (b)

4. DISCUSSION AND CONCLUSION

According to the findings of this research, both quantitative and qualitative, the research question of the present work was affirmatively answered, in line with all studies mentioned in the introduction. The improvement in learning engagement was proven to be independent of student gender. The findings, therefore, support the view that GIS-Based Projects provide a powerful platform where students engage in both in-class and out-of-class activities and gain multifaceted knowledge, skills, and experiences working on real problems, usually from the local community (Kerski et al., 2013). The findings also support the view of Liu and Zhu (2008), who in their research conclude that a learning environment supported by GIS technology can help teachers involve students in the educational process. However, the question that arises is: What other factors in the learning environment developed in this study may have played a role in improving student engagement? In the literature review, it was reported that learning involvement is determined by three main dimensions: behavioral, emotional, and cognitive engagement (Fredricks et al., 2004).

4.1 Behavioral Engagement

Both the students of Group1 and those of Group2 exhibited behavioral engagement, since they participated actively both in the planning and the realization of projects without exhibiting negative behaviors (Trowler, 2010). The level of active participation, however, varied between groups. Group1 particularly increased its active participation during gathering authentic data in the field, thus reinforcing the view that research projects in which students investigate real-world problems, combining fieldwork with GIS tools, can have a huge impact on student engagement (Favier & van der Schee, 2009. Other aspects of behavioral engagement involve the submission of questions or comments by the students to the educator (Trowler, 2010). According to the findings in both groups, there was an improvement in these indicators, with Group1 being clearly more improved especially in the statement, "I make comments or questions as far as the project is concerned, each time I see my teacher," a fact that may be related to the nature of the research project he/she participated in.

4.2 Emotional Engagement

According to Trowler (2010), students who are engaged emotionally usually go through emotional reactions like interest, enjoyment, or a sense of belonging. In this study, students developed emotional commitment, an important element that led to the improvement of their learning engagement. Students showed that they were sensitized towards society and its increased problems, developing a sense of accomplishment and enthusiasm since they felt they were contributing to solving social problems (Demirci et al., 2013). Group1 showed amelioration in this aspect of student engagement as well, and therefore it seems that the research project they worked on had the right mixture of activities that contributed to their emotional engagement, with the main being the fieldwork and the investigation of a local community issue.

4.3 Cognitive Engagement

Students who engage cognitively in the education process invest in their learning, seek to meet the demands of the lesson, and enjoy the challenge (Trowler, 2010). According to the findings, almost all indicators related to cognitive engagement improved for all the students, with Group1 excelling in this aspect of student engagement. Previous studies referenced in the present paper support that the technological obstacles to GIS incorporation into the education process, as well as the complex and very expensive GIS software, or lack of spatial data availability and lack of trained GIS staff, decrease the cognitive engagement of the students (Kerski, 2003; Kerski et al., 2013; Milson et al., 2012). Students who cannot see the possibilities of GIS, and the way they could use them to give added value to their research, do not intend to invest time in learning how to use them (Baker & White, 2003). However, an innovation of the present study that removes the aforementioned limitations is the utilization of the ArcGIS Online platform as a technological environment and, in addition, the adoption of the attitude that students should first learn to use GIS *and then* use them for learning purposes (Demirci et al., 2013; Favier, 2013, p. 80; Kotsopoulos, 2010). Thus, the learning environment adjusted as suggested applied a combination of the two elements, which means that before carrying out an activity for the project, students received a GIS tools workshop.

Overall, the factors that best influenced student engagement were not only the support of the learning environment by the GIS technology but also the application of the model PBL in the conduction of research projects as well as their topics. However, according to the findings of the present study as well as previous ones, the support of the research project by GIS technology gives added value to it, not to mention that the realization of such projects would be impossible without this technology.

In conclusion, the technologically supported learning environment that was developed in the present study can ameliorate student engagement, especially if this includes collection of authentic data in the field and addresses practical issues in the local community. The above conclusions do not differentiate according to gender. Moreover, the present study supports the view that students should first learn to use GIS and then exploit them to learn through them; that is, before conducting a learning activity based on GIS, a GIS workshop should be held. Finally, the cartography platform ArcGIS Online, even though professional, makes all needed elements available educationally.

5. LIMITATIONS

This section identifies the limitations that should be considered before generalizing the conclusions and conducting further research. As for the sample, this did not result from random sampling, but rather includes whole classes of a school with specific characteristics. The sample size, although reasonable for educational research on GIS, is probably considered modest by educational research standards. In addition, the sample distribution is 60% male and 40% female. The researcher was the teacher himself in the participating classes. This may have been an advantage with regards to prior knowledge of the strengths and weaknesses of the sample, but it may have deprived the observer of objectivity and neutrality. Finally, since the ArcGIS Online platform can be accessed at no cost there is no limitation as to its use.

6. FINAL REMARKS

The present study contributes to the international discussion on how GIS can be used in school education. Despite the limitations of the present study, it has contributed to the development of a new learning environment that incorporates the Project-Based Learning (PBL) methodology based on Web GIS technology, opening future educational avenues. This learning environment was utilized in conducting three effective research projects, with the findings from the educational research showing the multiple benefits that arise for the learning process. However, further areas need to be explored and improved:

- Other reliable and easier-to-use tools need to be developed to measure the impact of the use of GIS on the educational process.
- Further research is needed on how GIS technology can be integrated into the school curriculum and/or curriculum adaptation to leverage GIS.
- Finally, the professional development of teachers in the field is necessary, i.e., training them in how to use GIS technology in their lessons.

CONFLICT OF INTEREST

The author declares that they have no conflict of interest.

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